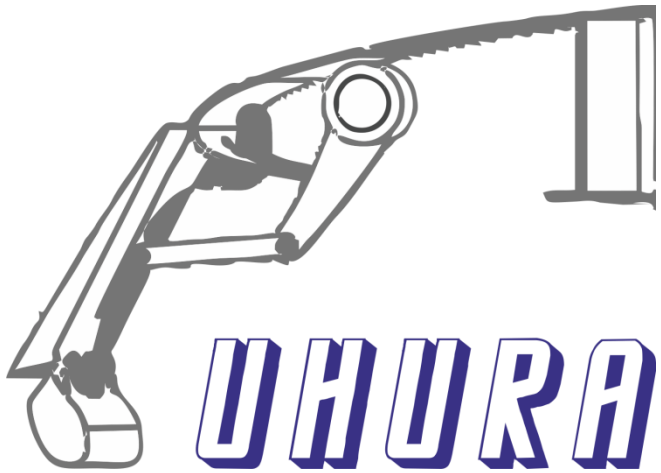

A 2D Validation Experiment for Dynamic High-Lift System Aerodynamics

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M. Schmidt – DLR Engineering Systems House , Braunschweig, Germany
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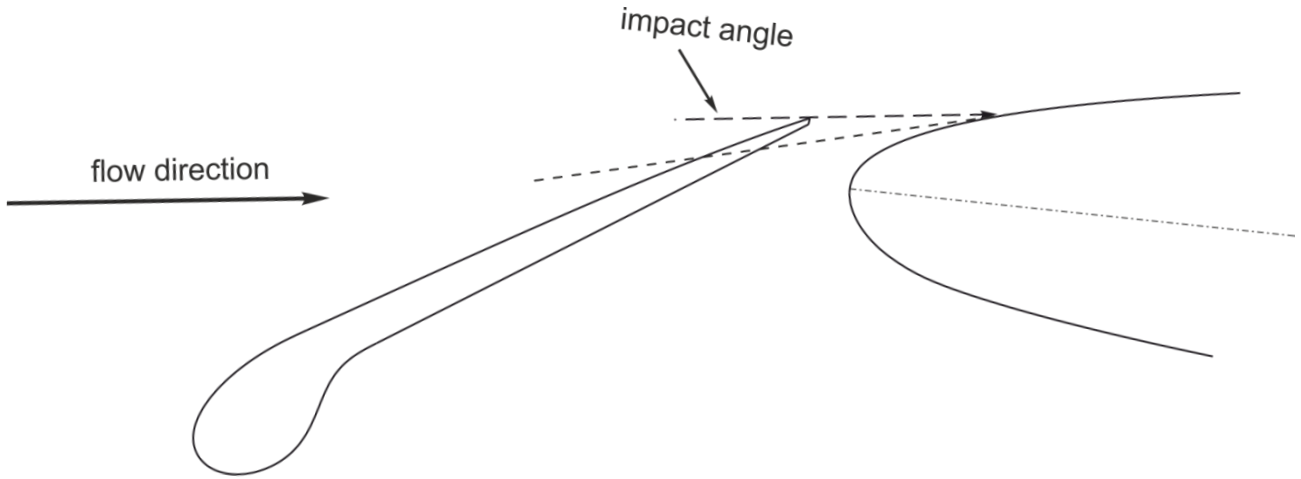
Horizon 2020
European Union funding
for Research & Innovation

Why Krueger flaps for laminar wings?

/ Requirements for leading edge high-lift system

- / Avoid disturbance of wing upper side
- / Provide shielding of leading edge against contamination (insects, dust, moisture)



Motivation

Identified issues

- deployment path critical in case of actuation failure/jamming
- deployment sequentially or in groups recommended

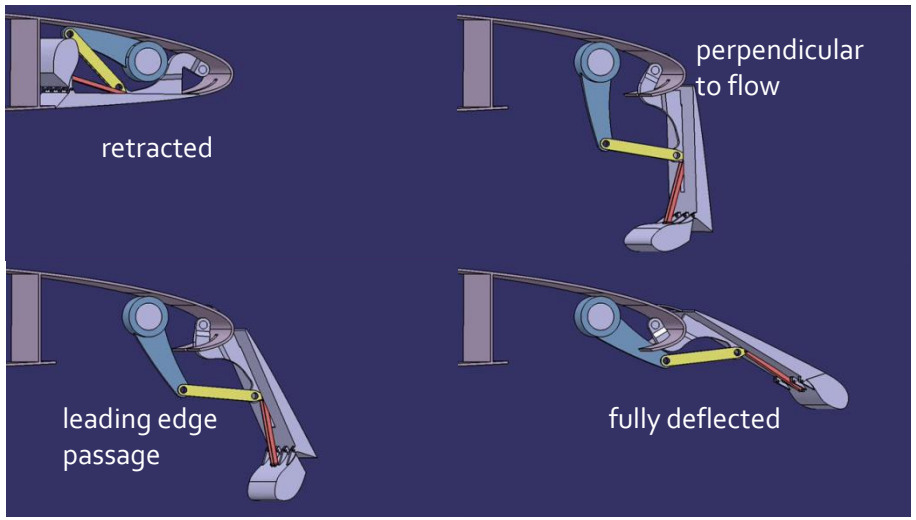
Challenges

- limited overall deployment time increases required deployment speed
- unsteady effects during deployments likely
- need for validated simulation methodology

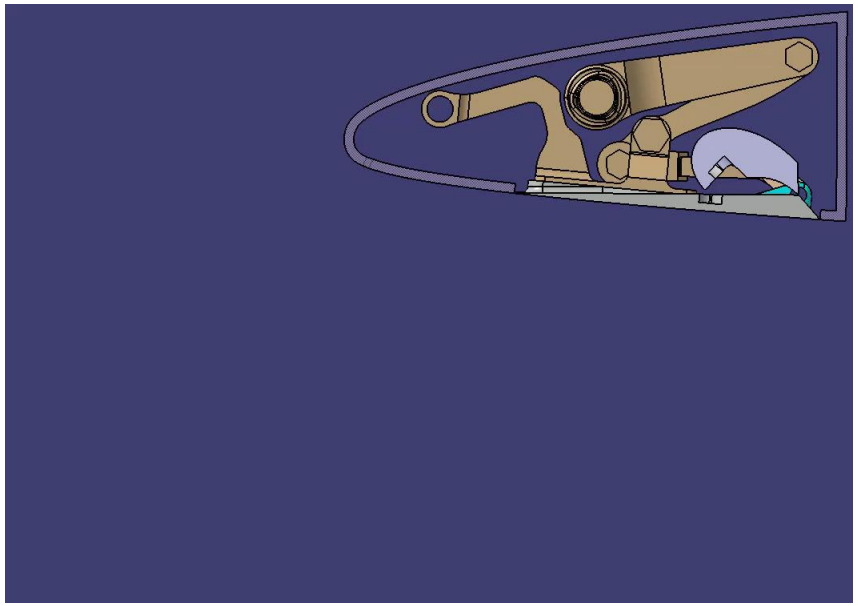
Source: airliners.net © Teemu Tuuri

Source: youtube.com © user/Jet3TV

Aerodynamic challenges

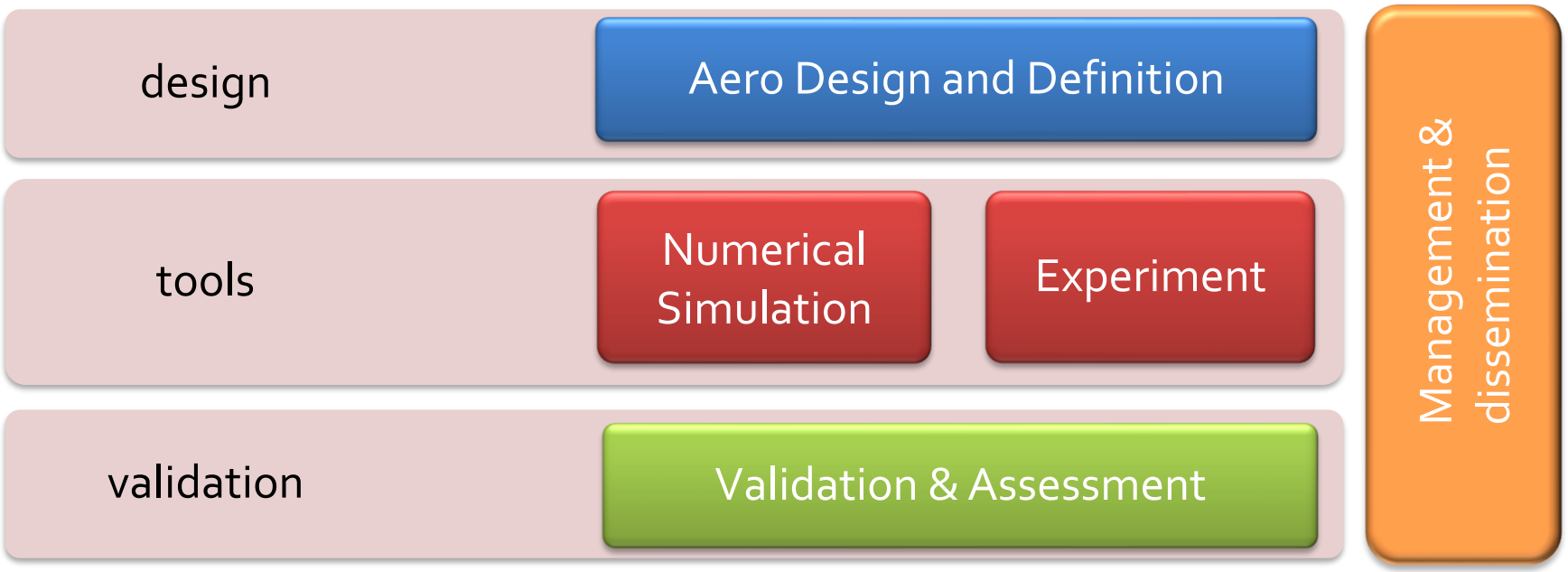


Specific critical conditions

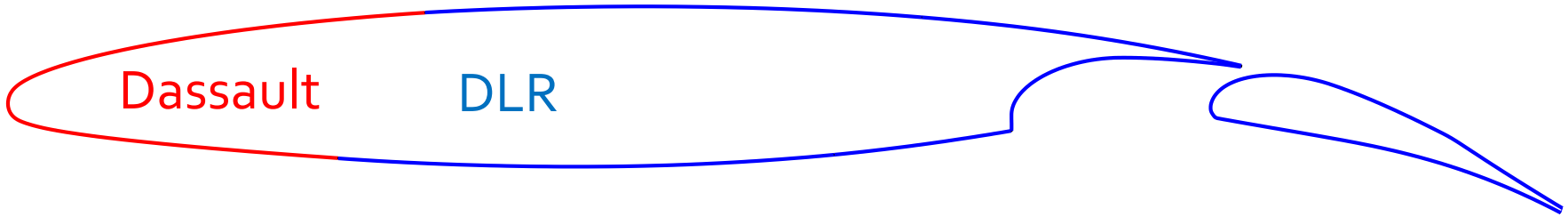


Targeted deployment time: 1s

UHURA project



Background
DLR-F15-LLE airfoil shape



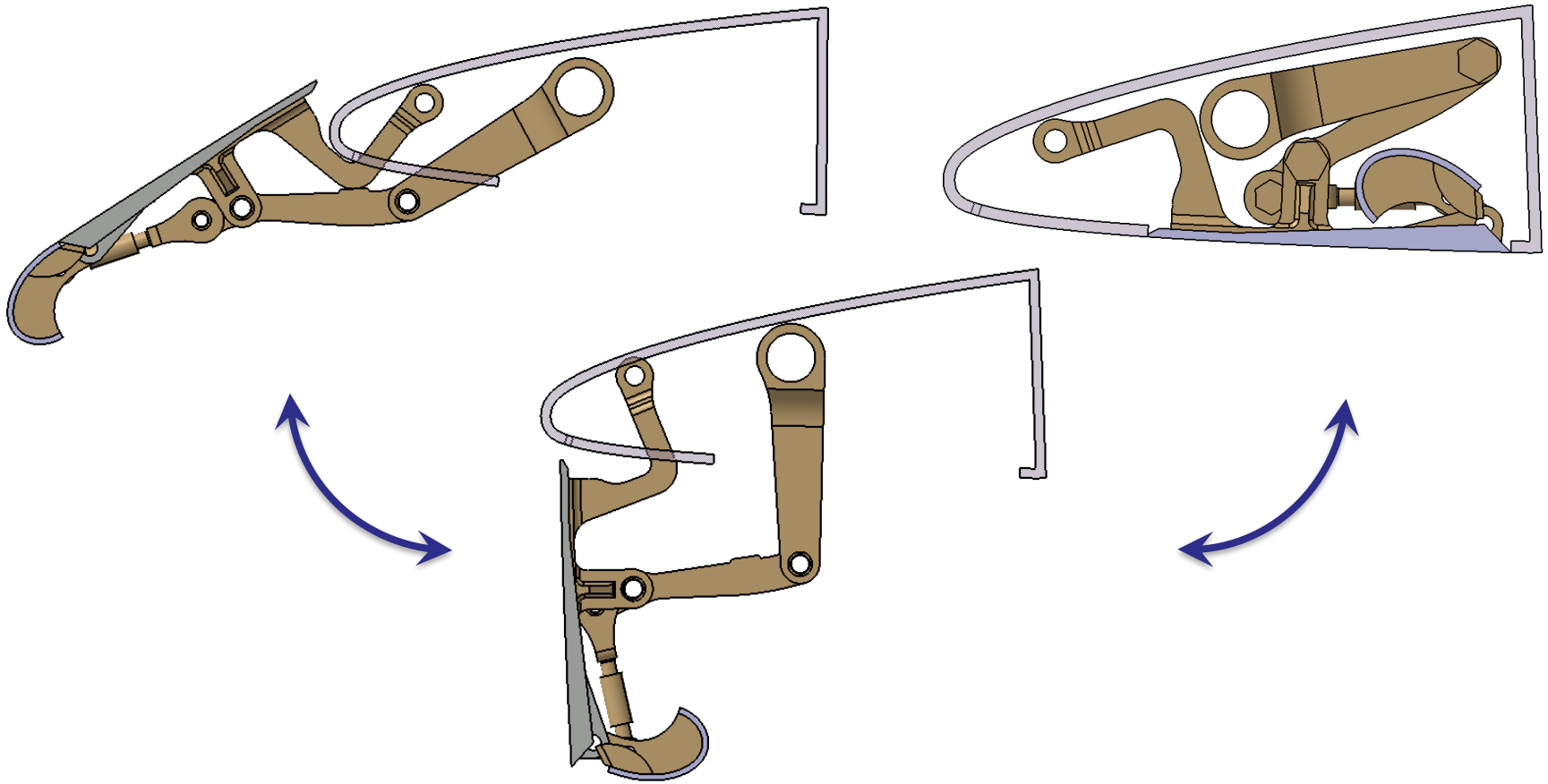
/ laminar wing version of the DLR-F15 airfoil, leading edge designed by Dassault

/ developped in CleanSky - Smart Fix Wing Aircraft

Kinematics design

Gooseneck type kinematics

- compact design
- minimum number of moving parts
- fully stressed



Wind tunnel experiments

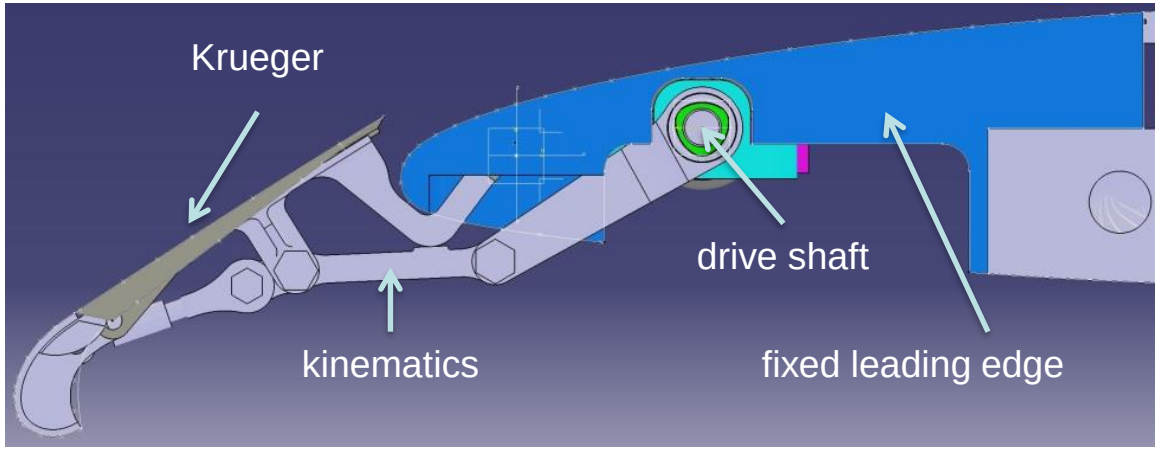
ONERA-L1, closed test section, DLR-F15, 2D wall-to-wall: medium Reynolds number (approx. 2-3x10⁶), detailed flow field with PIV, influence of deflection rate.

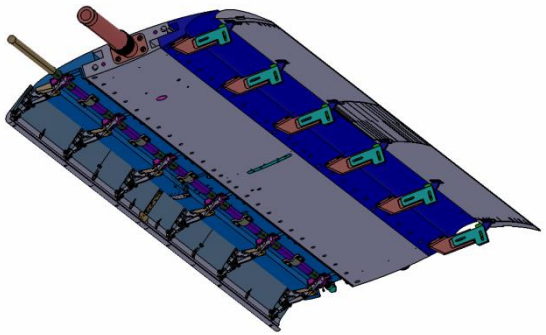
DNW-NWB, closed test section, DLR-F15S, 2,5D cantilever wing: influence of sweep, wake measurements (5-hole probe rake), possibly SPR

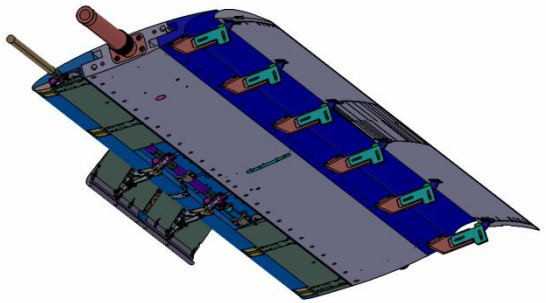
DNW-LLF, open test section, DLR-F15LS, 2D und 2.5D: realistic actuation & kinematics, effect of Reynolds number (ca. 6x10⁶), effect of span loading, detailed flow field with PIV, force integration, Krueger flap deformation

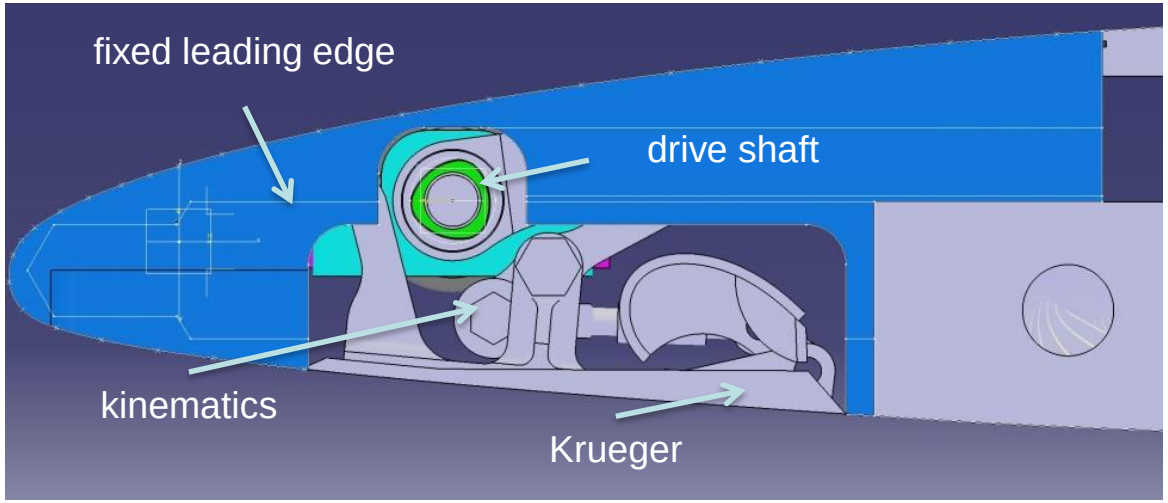
DLR-F15-LLE model
Implementation into leading edge

- solid aluminium leading edge part
- Kinematics and Krueger mounted at distinct actuation stations
- part span and full span







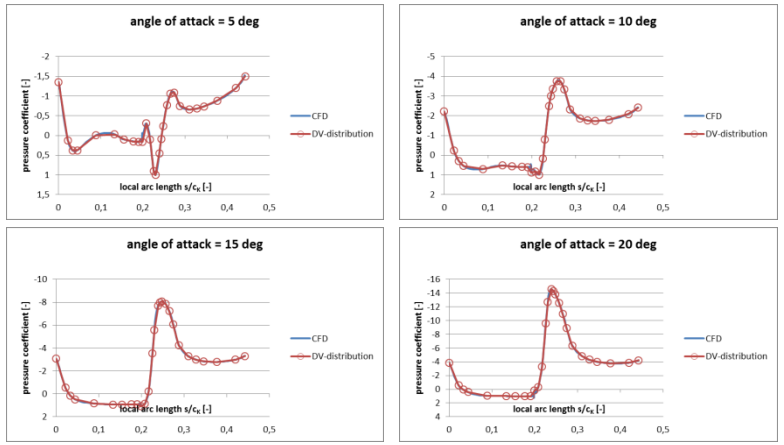


DLF-F15 challenge

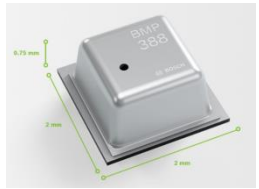
- Manufacturing of 6+1 kinematic stations
- High tolerance machining
- Small dimensions
- No rigging capabilities
- No excess friction in ALL hinges and mountings
- Secured fo 10k cycles!

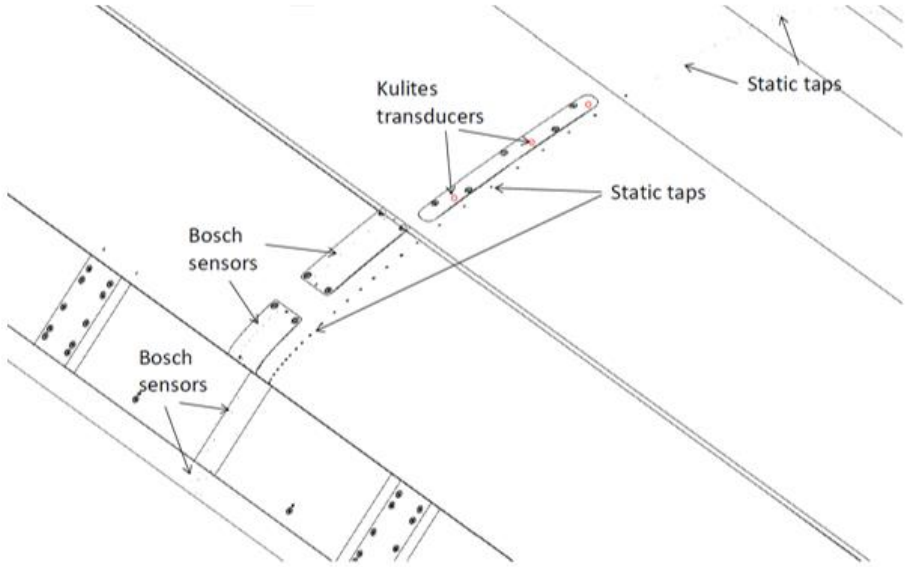
instrumentation
pressure measurements

- 52 pressure porbes on leading edge and Krueger flap
  - obtain reliable prediction of aerodynamic forces by pressure integration
  - less than 1% integration error on Krueger forces



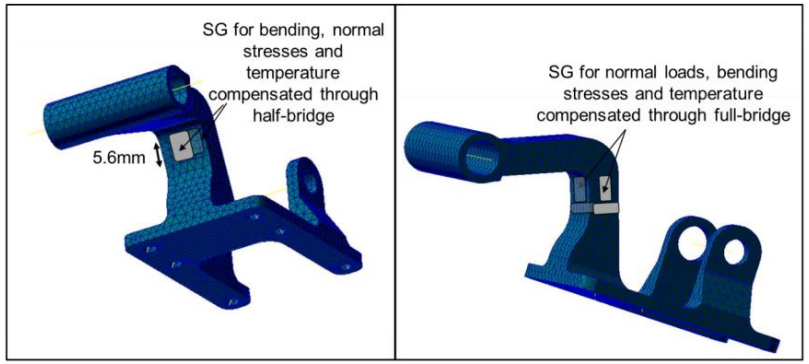
- dynamic pressure measurements
  - Bosch BMP388 pressure MEMS sensor
  - six circuit boards implemented in model
  - low cost solution
  - ~100 Hz can be resolved

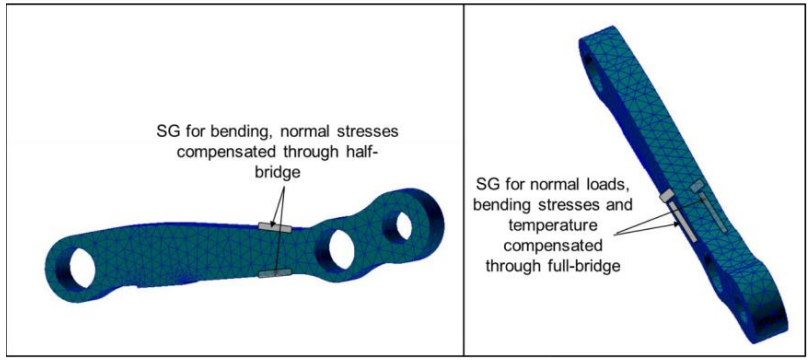


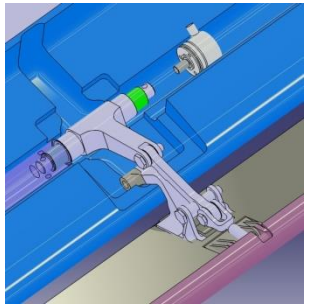


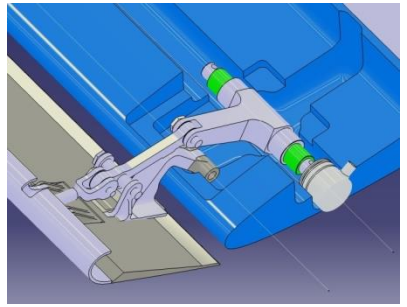
instrumentation
strain and position sensor

- **Internal stresses**
  - strain gauges to be implmented on goose neck
  - constant cross section
  - torque sensor at drive
- **Krueger flap position**
  - position sensor at end of drive shaft
  - position sensor at drive
  - capability to measure angular disalignment



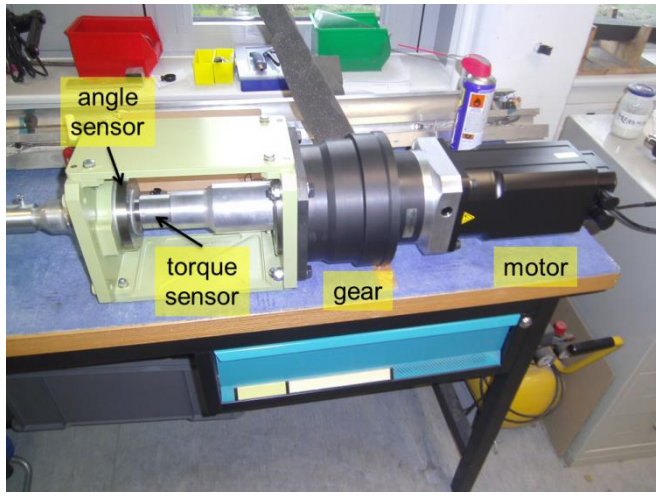


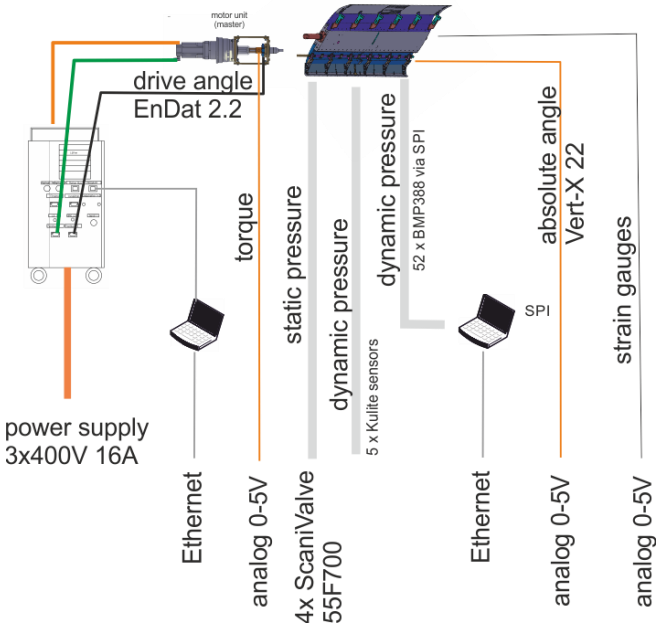




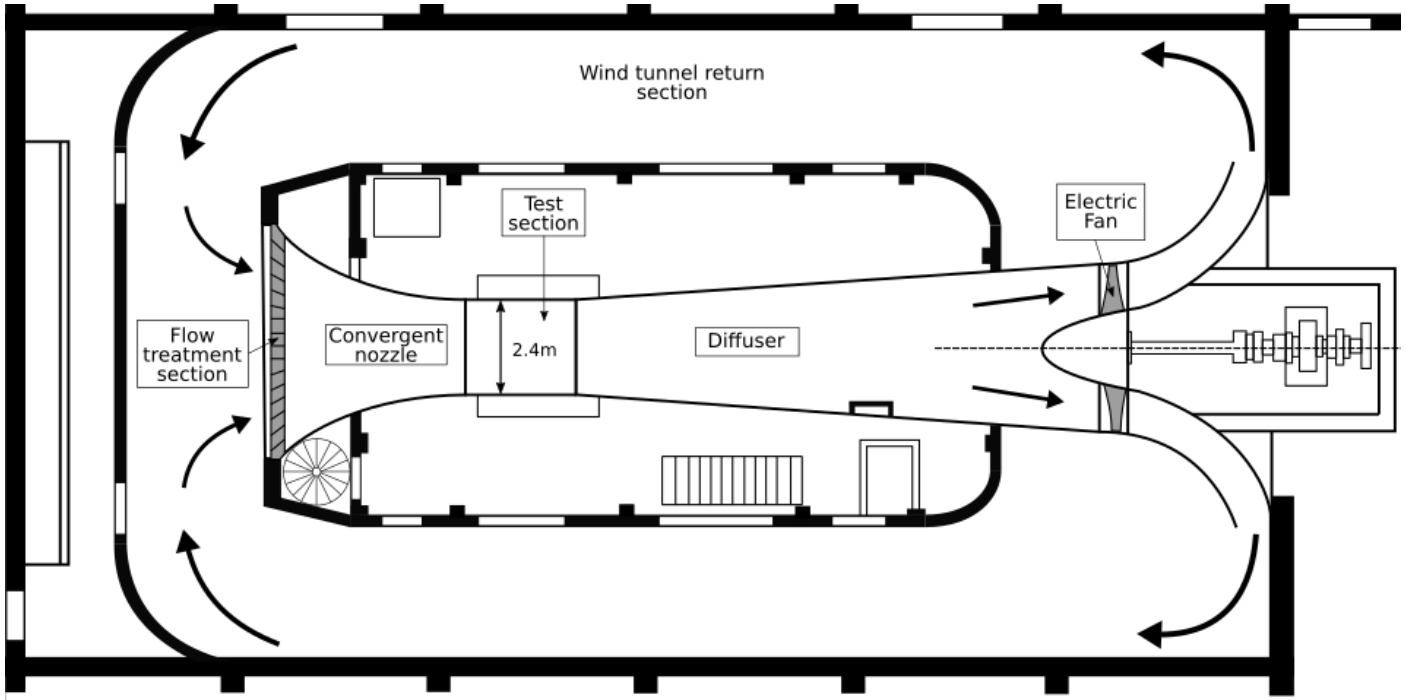
Actuation architecture

- **Drive system**
  - Available from AFLoNext GBD
  - Digital controlled geared servo motors
  - 550Nm @ 360°/s
  - Motor control by Ethernet connection
- **Measurements**
  - Strain and position by analog signals
  - 220 static pressure ports
  - 57 dynamic pressure ports





Wind tunnel facility
ONERA L1 tunnel, Lille



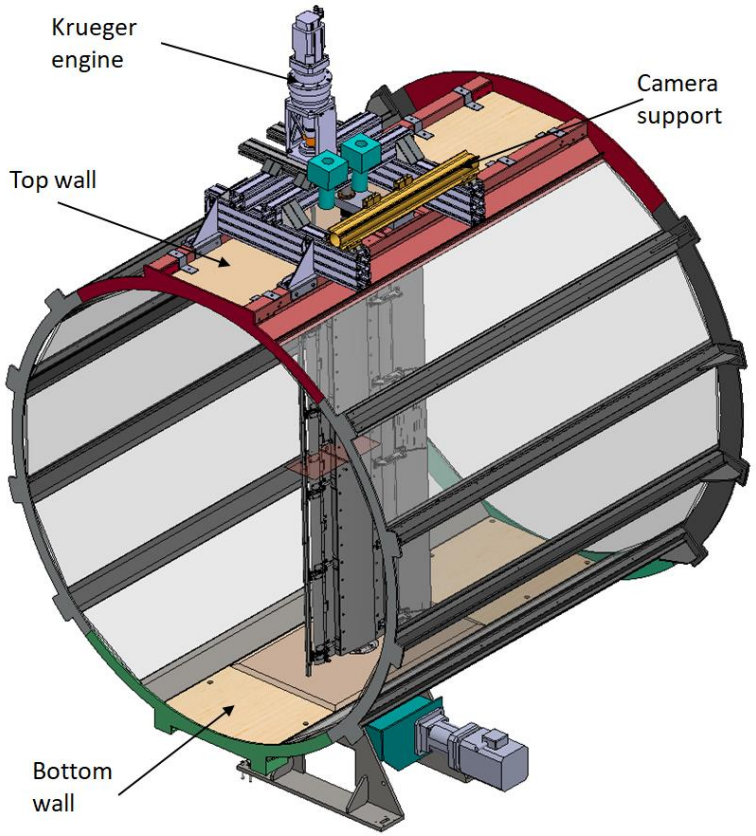
- Return wind tunnel with a 2.4m diameter test section
- Maximum velocity up to 70 m/s
- Dodecagonal test section with modular panels / wide optical access

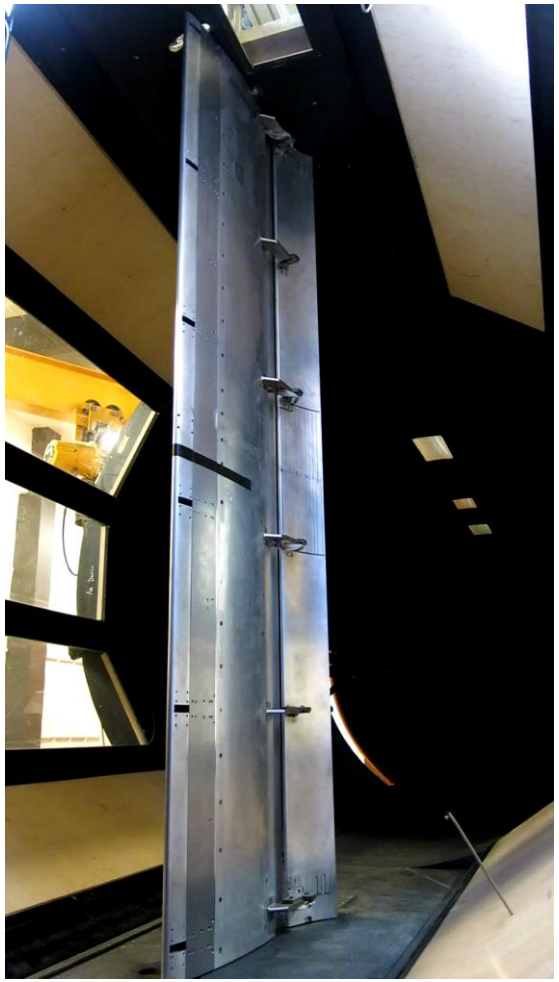
Wind tunnel set up

/ Wing is mounted vertically – Krueger engine on the top of the section

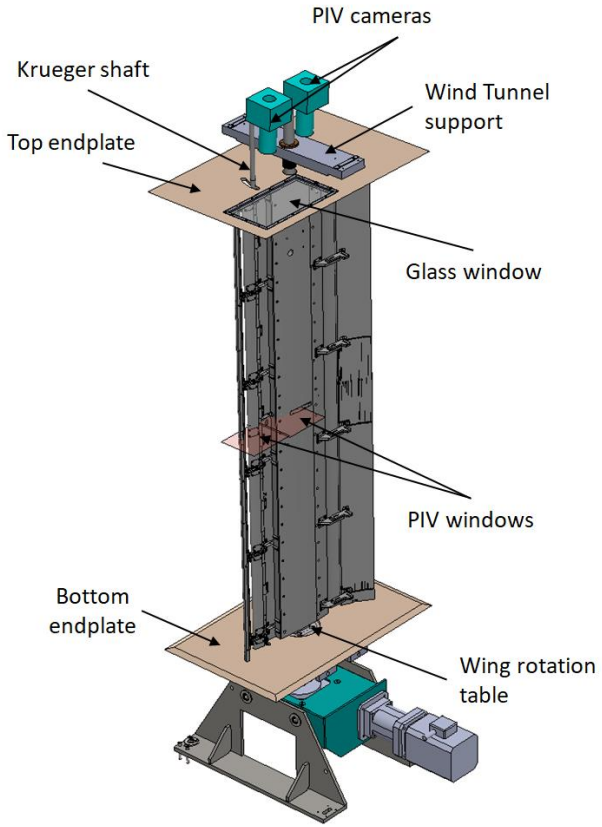
/ new end plates with optical windows

/ PIV measurement plane located at mid-span section

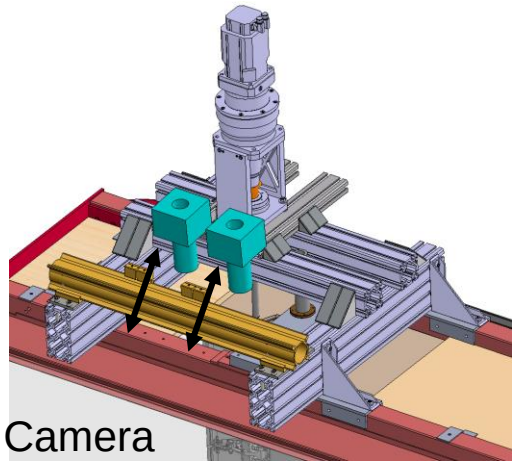


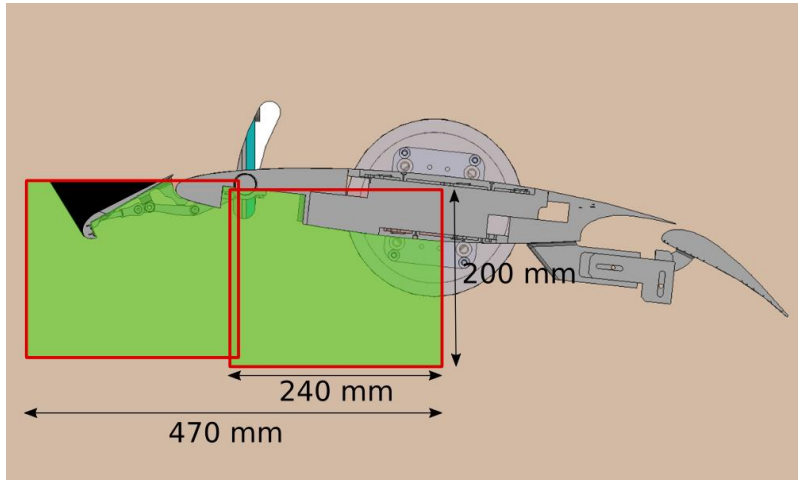


2D2C PIV set up



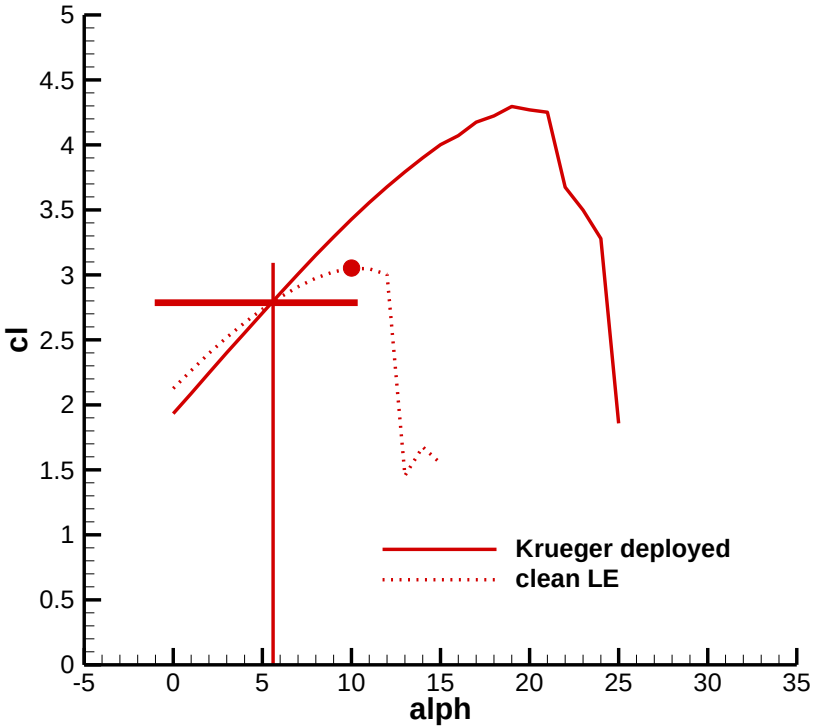
- Dual cavity Nd:YAG laser 2 x 380mJ
  - acquisition rate 10Hz
- 2 x CMOS Cameras
  - 1024x1024 pixels
- 2 PIV windows
  - 240 x 200 mm
- PIV measurements @ 6° AoA
- Phase lock acquisition
  - 40 snapshots per deployment
  - 3.6° resolution


Camera main support



Krueger flap operation

- full dynamic deflection at maximum angle of attack is neither feasible nor required
- envelope:
  - full angle-of-attack range (up to stall) in steady mode only
  - dynamic mode only at reasonably low angles of attack
- for operating loads: choose angle of attack safe for Krueger retraction
  - C_L-condition: C_L = 2.9
  - α-condition: α = 6°



Test matrix

Static tests

- $V_\infty = \left\{30\frac{m}{s}; 45\frac{m}{s}\right\}$
- $Re_c = \{1.15 \times 10^6; 1.73 \times 10^6\}$
- AoA sweep
  - $\alpha = [0°; 30°]$
  - $\delta_K = \{0°; full\}$
- Krueger sweep
  - $\alpha = 6°$
  - $\delta_K = \{0°; 25\%; 50\%; 75\%; 100\%\}$

Dynamic tests

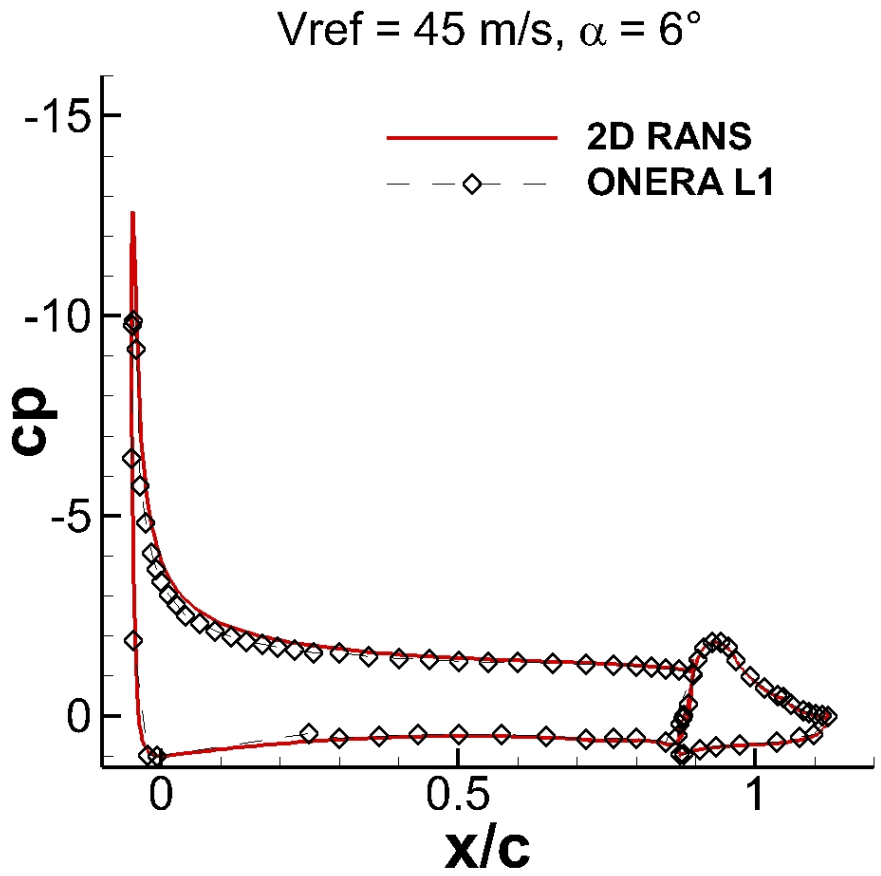
- $V_\infty = \left\{30\frac{m}{s}; 45\frac{m}{s}\right\}$
- $Re_c = \{1.15 \times 10^6; 1.73 \times 10^6\}$
- $\alpha = 6°$
- $\delta_K = [0°; full]$
- $T = \{1\ s; 2\ s; 4\ s\}$

Initial results of ONERA L1 test

verification of target flow condition

- pressure distribution at target angle of attack shows good agreement on wing and flap
  - good agreement of physical and geometrical angle of attack
  - no AoA adjustment needed

- stall occurs at lower angles of attack in experiment
  - no transition tripping applied
  - no means to prevent side wall stall
  - relatively high blockage

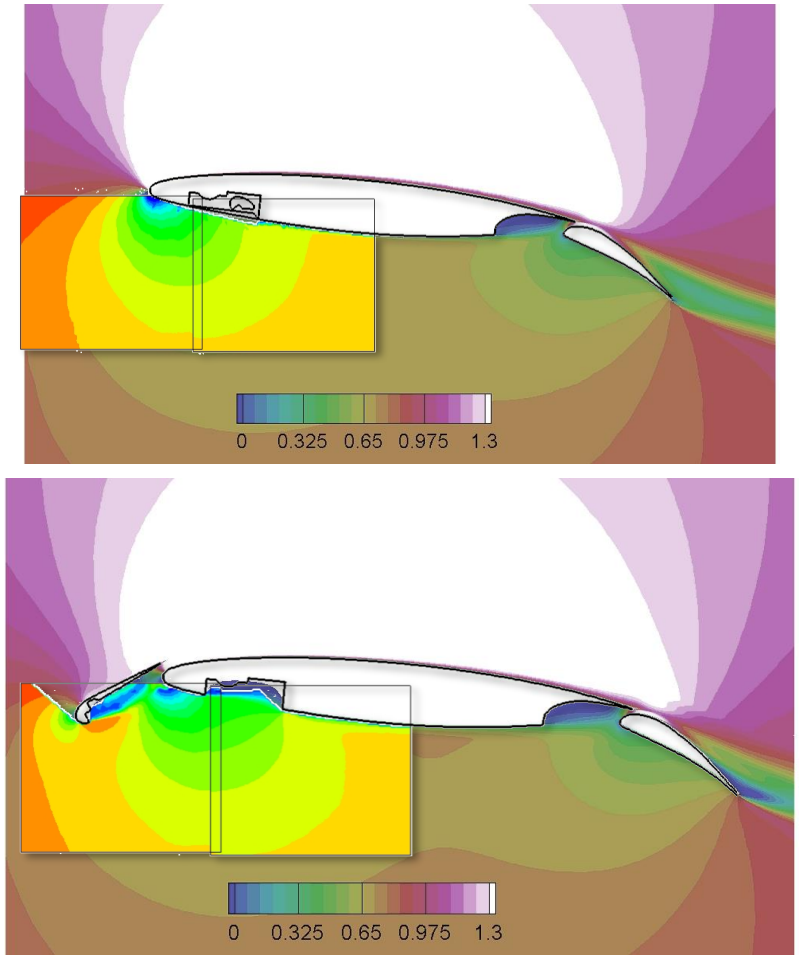


Initial results of ONERA L1 test

flow field comparison

- overlay of PIV data with 2D RANS CFD
- comparison at target AoA=6°
- Krueger fully retracted and fully deflected

- good agreement of shape and levels of iso-velocity contours
- details (Krueger rear side flow, stagnation line) match between CFD and PIV



Summary and next steps

/ summary

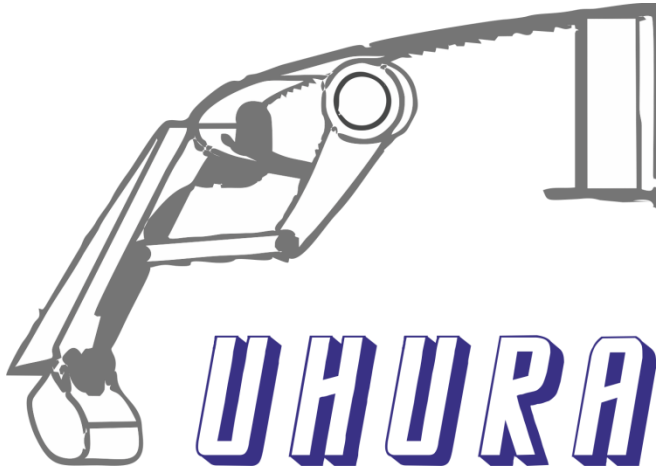
- / successfully setup wind tunnel experiment for dynamic high-lift system deployment
- / first results show promising comparison to prediction
- / data analysis of dynamic tests ongoing

/ upcoming

- / cantilever wing tests in DNW-NWB in March 2021
- / large scale test in DNW-LLF April 2021
- / completion of ONERA L1 test matix in summer 2021

Thank you

visit us at uhura-project.eu



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Horizon 2020
European Union funding
for Research & Innovation